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Fire Episodes in the Inland Northwest (1540-1940) Based on Fire History Data

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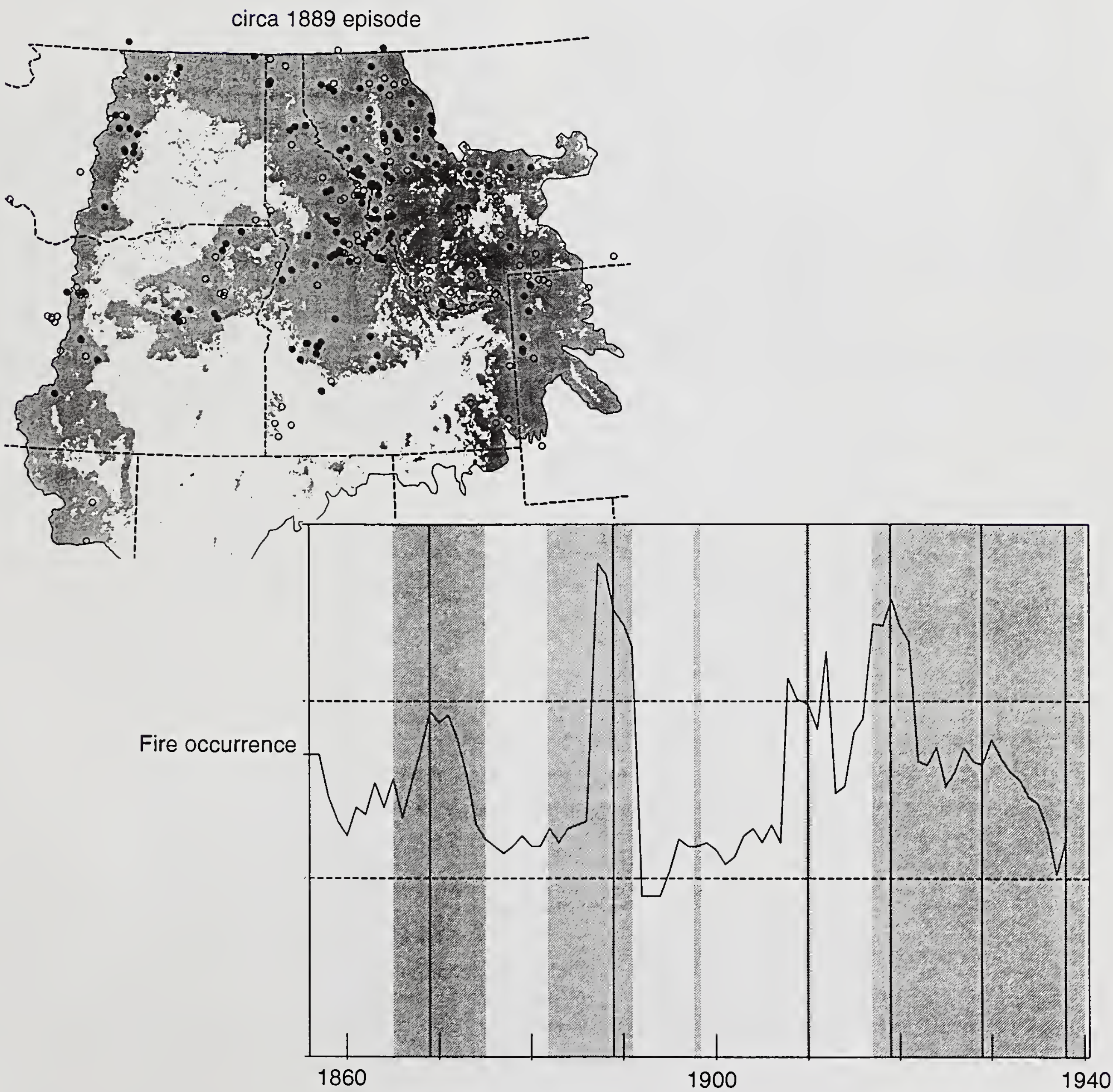

The Authors

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Research Summary

Information from fire history studies in the Northwestern United States was used to identify and map "fire episodes" (5 year periods) when fire records were most abundant. Episodes of widespread landscape-scale fires occurred at average intervals of 12 years. Mean annual acreage burned was calculated based on estimated areas of historical vegetation types with their associated fire intervals from the fire history studies. An average of about 6 million acres of forest and grass and shrubland burned annually within the 200 million acre Columbia River Basin study region, and especially active fire years probably burned twice this much area. For comparison, the largest known fire years since 1900 have each burned 2 million to 3 million acres in this region. We also compare the occurrence of regional fire episodes to drought cycles defined by tree-ring studies.

Acknowledgments

This presentation was difficult to develop because the data came from diverse sources with considerable variation in methods and reporting. Several people gave valuable advice and encouragement to help develop a more useful product: James K. Brown (retired), Elizabeth Reinhardt, and Mark Finney of the Intermountain Fire Sciences Laboratory in Missoula, MT; David A. Thomas of the USDA Forest Service, Intermountain Region; Richard Lasko of the USDA Forest Service, Northern Region; and Thomas Swetnam of the Laboratory of Tree Ring Research at the University of Arizona, Tucson. Helen Y. Smith and Michael A. Krebs provided valuable assistance in developing the manuscript for publication.

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Fire Episodes in the Inland Northwest (1540-1940) Based on Fire History Data

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Introduction

One goal of the Interior Columbia Basin Ecosystem Management Project (ICBEMP) is to develop information to aid broad-scale management of Federal lands for a large area of the Northwestern United States (Haynes and others 1996). Information on the historic scale of fire in the ICBEMP study region (fig. 1) is useful as an ecological benchmark because fire has been important in shaping vegetation structure and composition in this region for thousands of years (Johnson and others 1994). Detailed maps and records of fires extend back only a few decades and are not available for the historic fire period, before fire suppression and land use changes influenced the role of fire (Agee 1993). However, long-term records of fire history are available from many individual sites based on studies of fire scars on old trees and stumps and ages of trees that became established after past fires (Barrett and Arno 1988).

In conjunction with the ICBEMP, Barrett (1995a) compiled information from fire history studies within the ICBEMP study region, allowing us to review the role of historical fires on a regional scale by mapping locations where past fires were detected. We recorded the fire locations on a regional map, and we report the periods (termed fire episodes) when these fire records were most abundant between 1540 and 1940. By 1940, fire suppression was effective in limiting the role of natural fire throughout the region (Pyne 1982).

Maps of the fire episodes represent 5 year periods having abundant and widespread fire evidence, from fire scars on trees and age-classes of trees that regenerated after fires (Agee 1993; Barrett and Arno 1988). While data do not provide measurements on the extent and pattern of individual fires, collectively they offer evidence of historical fires on a broad landscape scale—evidence previously unavailable. We also examine the relationship of fire episodes to regional drought as identified by dendrochronological (tree ring) records (Stokes and Smiley 1968).

To estimate the extent of historical burning in the ICBEMP study region, we calculated mean annual acreages burned based on estimated acreages of historical vegetation types (Losensky 1995) and their associated mean fire intervals—average number of years between fires on any site within the vegetation type. We compare these estimates of historical burning with areas burned in recent decades. This information on the historical role of fire should be useful for understanding fire as a landscape-scale process.

Methods

Three aspects of fire history were investigated: (1) identifying and mapping regional fire episodes, (2) inspecting relationships of regional drought to fire episodes, and (3) estimating mean annual area burned throughout the ICBEMP region.

First, a literature search was conducted to obtain all published fire history studies in the ICBEMP region. Ecologists in the region were contacted for copies of unpublished fire history data. Master fire chronologies (Romme 1980) and associated latitudinal and longitudinal coordinates (to the nearest minute) were obtained for each study area, that ranged in size from a single point, such as a fire-scarred tree, to an entire watershed experiencing stand-replacement burning. Fire history studies provided most of the information, but data on fires greater than 10 acres in size were obtained from fire atlases maintained by land management agencies, early newspapers, and other historic records. In each case one fire record was entered in the database for each fire year in each fire chronology. The database was summarized in three ways.

Most fire history studies were based on tree ring counts to estimate years of fire scars without dendrochronological cross-dating to enhance dating precision (Madany and others 1983). As a result, many fire year estimates for pre-1900 fires are probably within plus or minus 2 years of the actual date (Arno and Sneck 1977; Arno and others 1995; Fiedler and Steele 1992). Consequently, rather than individual years, we analyzed fire episodes, which we define as 5 year periods with abundant evidence of fire in the ICBEMP study region. To identify fire episodes, a running 5 year tally

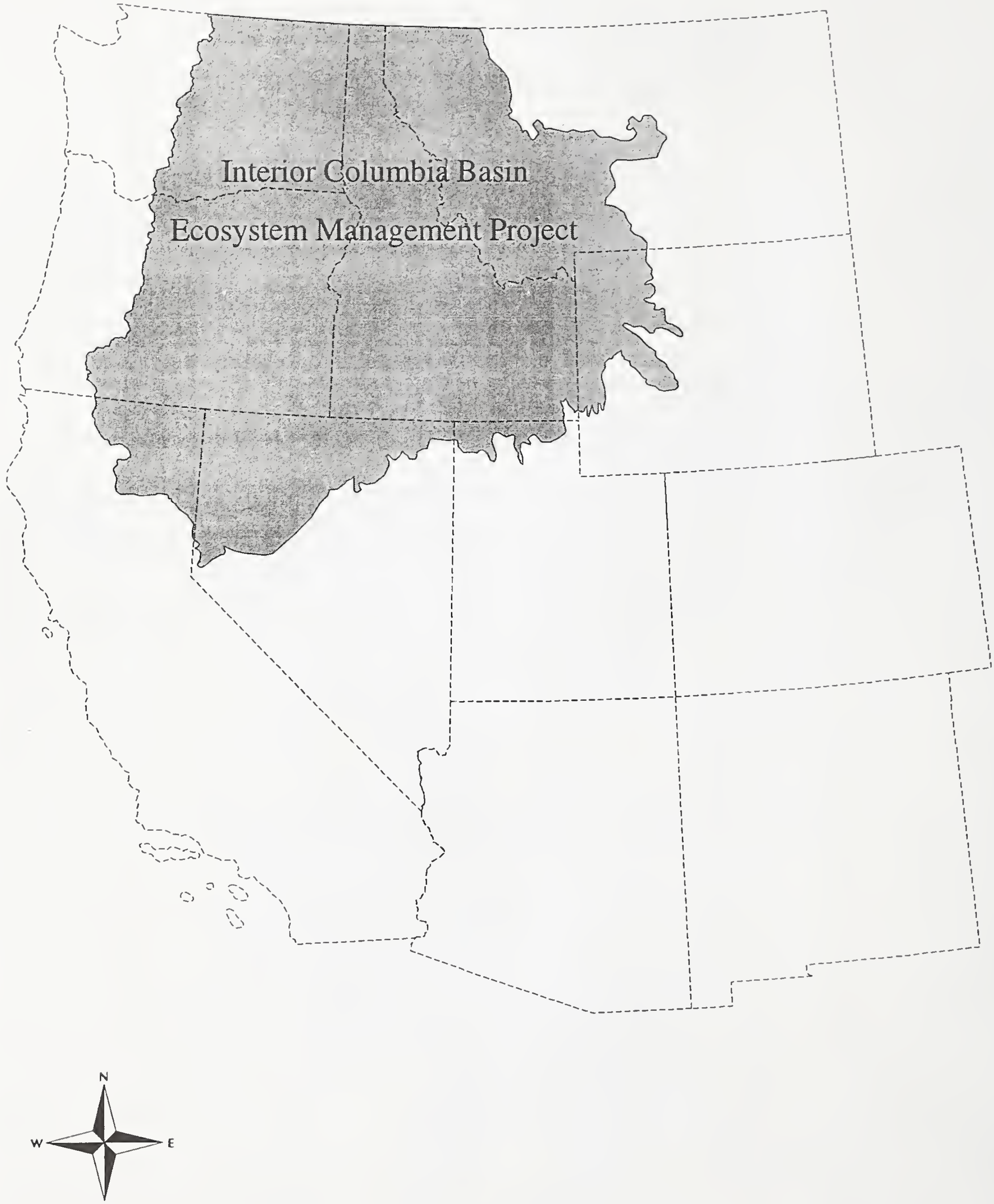


Figure 1—Outline of the Interior Columbia Basin Ecosystem Management Project (ICBEMP) study region (Scientific Assessment area).

of fire year estimates was conducted, beginning with 1500 ±2, 1501 ±2, 1502 ±2, and so forth up to 1940. A running tally was used to reduce the effect of estimation errors by smoothing the annual frequency curve (Diggle 1990; Howarth and Rogers 1992). For instance, ca. 1889 fires are represented by all data indicating fires between 1887 and 1891.

The fire history database (Barrett 1995a) was also compared with dendrochronological records of regional drought (Barrett 1995b). Fire occurrence (expressed in percent of sites) was summarized by first averaging the 5 year running tally (divided by 5) used in fire episodes and then dividing by the average number of potential recording sites. The latter are sites that could have recorded a given fire episode because they had previously recorded fires (Arno and Sneck 1977; Kilgore and Taylor 1979). Results of the fire occurrence analysis were graphed relative to periods of substantially below average tree ring growth (on dry sites) indicative of regional drought as identified by Keen (1937) and Graumlich (1987).

To quantify acreages burned, we started with estimates of the areas occupied by historic vegetation types in this region from the ICBEMP study by Losensky (1995). Estimates are based on compilation and synthesis of numerous early 1900s forest and vegetation surveys for individual counties and other areas throughout the region. We took the area of each major vegetation type and divided it by the corresponding mean fire intervals (site fire interval as in Arno and Petersen [1983]) to estimate the mean annual area burned. Where possible, mean fire intervals for vegetation types were taken from Barrett's (1995a) database. For types having limited data in the ICBEMP region, mean fire intervals were estimated using available literature from the Western United States.

Results and Discussion

Regional Fire Episodes

The database contains 4,360 fire records from 122 sources (fire history studies, fire atlases, written accounts). The records are from 324 sites with discrete latitudinal and longitudinal coordinates for geographic information system (GIS) mapping. Most data were from 108 fire history studies with a total of 979 sample stands. About one-third of these studies have been published (Agee 1993). The data are unevenly distributed across the region, with about 80 percent coming from the northern Rocky Mountains (fig. 2).

About 73 percent of the fire records were obtained from fire scars, 17 percent from fire atlases and other written records, and 10 percent from analysis of postfire age classes of seral trees (Barrett and Arno 1988). About 90 percent of all fire records were from the following four cover types: ponderosa pine (*Pinus ponderosa*), lodgepole pine (*P. contorta*), interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca*), and western larch (*Larix occidentalis*). These four were the most extensive historic forest cover types in the Interior Columbia River Basin, comprising about three-forths of the forested area (Losensky 1995).

Our maps (fig. 3 to 37) show fire locations during the 35 "fire episodes" between 1540 and 1940 when fire data were most abundant. Each fire episode map shows all potential recording sites as well as all sites that actually recorded fire. Visual examination of the fire episode maps indicates at least nine instances of extensive fire activity in the ICBEMP study region prior to 1900. Circa 1889 fires (fig. 33) provide the most compelling evidence of extensive burning (table 1) and widespread 1889 fires are confirmed by numerous contemporary accounts, such as in the *Idaho Daily Statesman* (Boise, ID 1889) and other newspapers (Taylor 1989). Fire episodes centered at 1869, 1856, 1846, 1833, 1823, 1802, 1784, and 1778 also show an impressive extent of fires. Data diminish markedly prior to the mid-1700s because of decreasing numbers of trees old enough to record earlier fires. Still, as far back as the 1580s (fig. 7, 8) the regional extent of fire episodes remains impressive. The average number of years between the 35 fire episodes is about 12.

Recent extensive fire occurrences in this region, such as in 1988, 1994, and 1996, produced a large proportion of stand replacement burning in all forest types (Babbitt 1995). By comparison, pre-1900 fires were characterized by less stand replacement burning and more mixed severity fire and nonlethal underburning (Agee 1993; Brown 1995; Brown and others 1994; Quigley and others 1996). Much of the pre-1900 burned area was in ponderosa pine and pine-mixed conifer types that burned frequently but primarily in nonlethal underburns (Agee 1993; Arno and others 1995).

Area Burned

Our data cannot be used to deduce whether the episodes of widespread fire (fig. 3 to 37) resulted from numerous small fires or from extensive landscape burning. However, calculating mean annual burned acreages for major vegetation types provided some quantification of the extent of burning during the fire episodes. For example, Losensky (1995) estimated that historically the ponderosa pine type occupied about 24 million acres, while sagebrush and bunchgrass types covered about 100 million acres. Average pre-1900 fire intervals were 20 years (site fire intervals as described in Agee 1993; Arno and Petersen 1983) in ponderosa pine based on 252 stands in the data base (Barrett 1995a). A conservative estimate of 25 years was used for Columbia Basin sagebrush and grass (Agee 1993; Wright and Bailey 1982). Based on

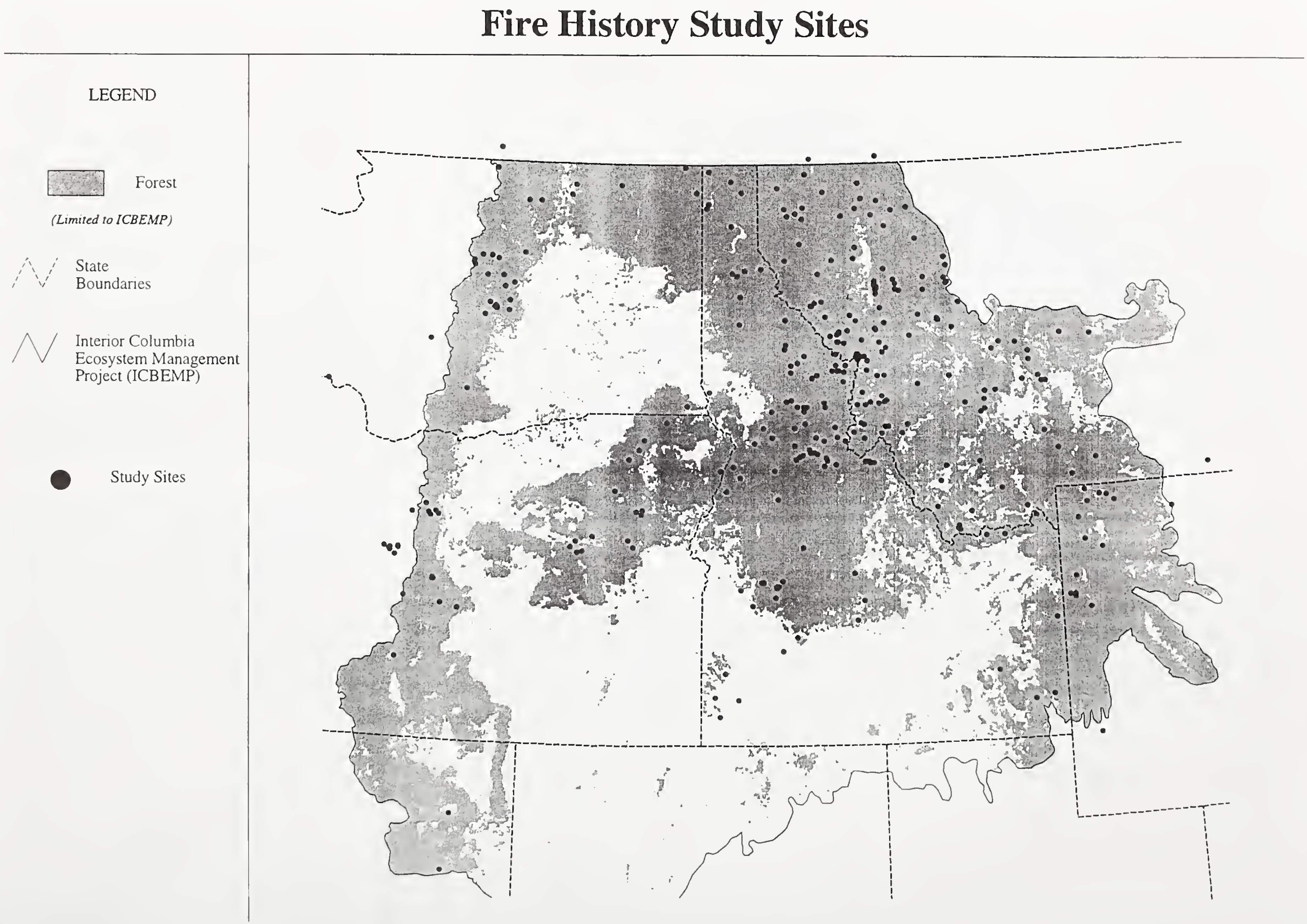
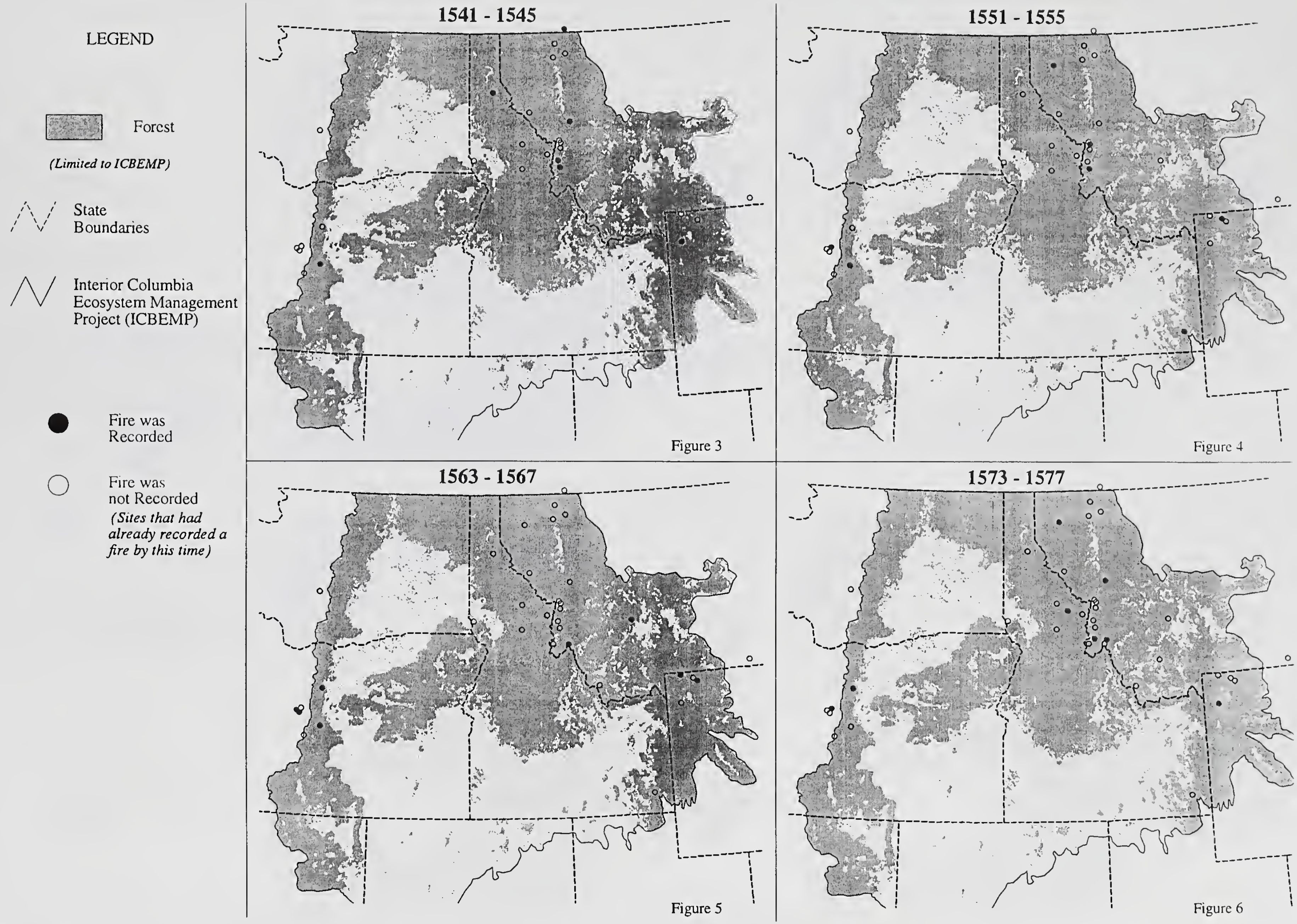


Figure 2—Locations of the fire history sites.



Figures 3-37—Fire episodes—the most abundant and widespread fire occurrences—between 1540 and 1940 at the 324 sites.

LEGEND

Forest

(Limited to ICBEMP)

State Boundaries

Interior Columbia Ecosystem Management Project (ICBEMP)

Fire was Recorded

Fire was not Recorded *(Sites that had already recorded a fire by this time)*

1579 - 1583

Figure 7

1592 - 1596

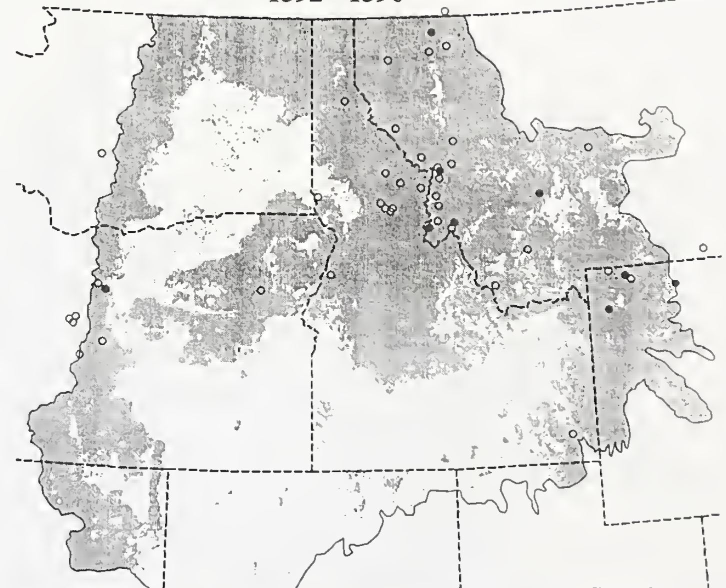


Figure 8

1600 - 1604

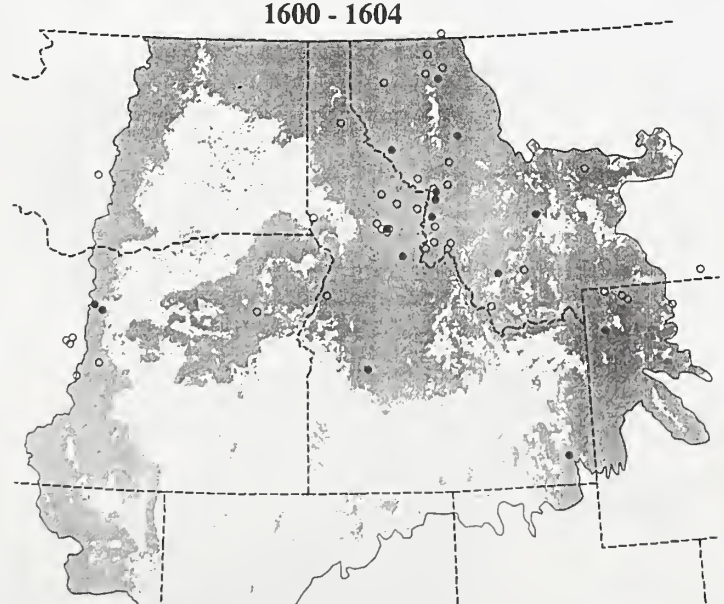


Figure 9

1628 - 1632

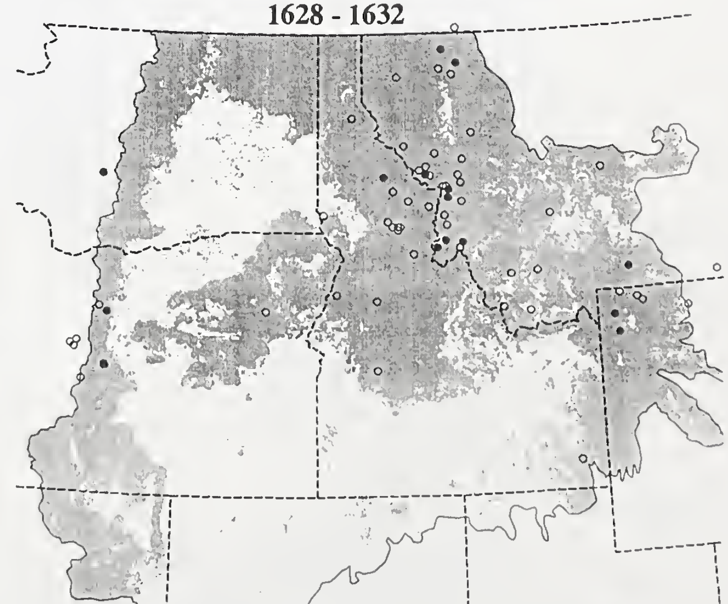


Figure 10

LEGEND

Forest

(Limited to ICBEMP)

State Boundaries

Interior Columbia Ecosystem Management Project (ICBEMP)

Fire was Recorded

Fire was not Recorded *(Sites that had already recorded a fire by this time)*

1632 - 1636

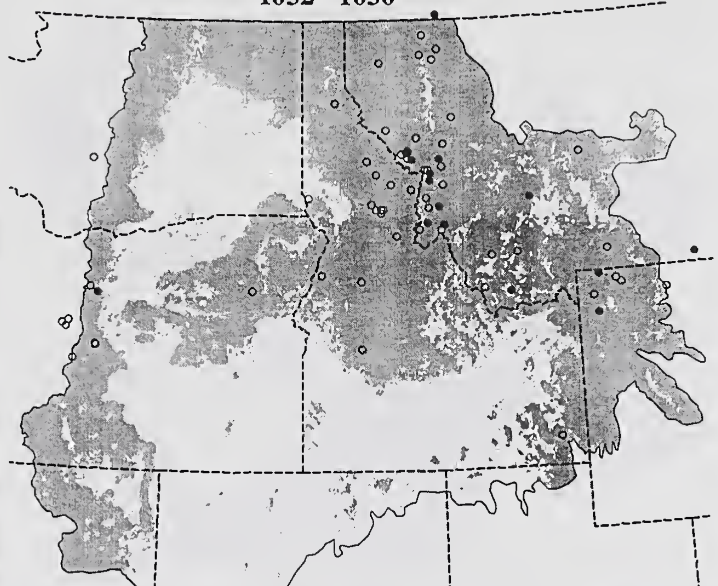


Figure 11

1640 - 1644

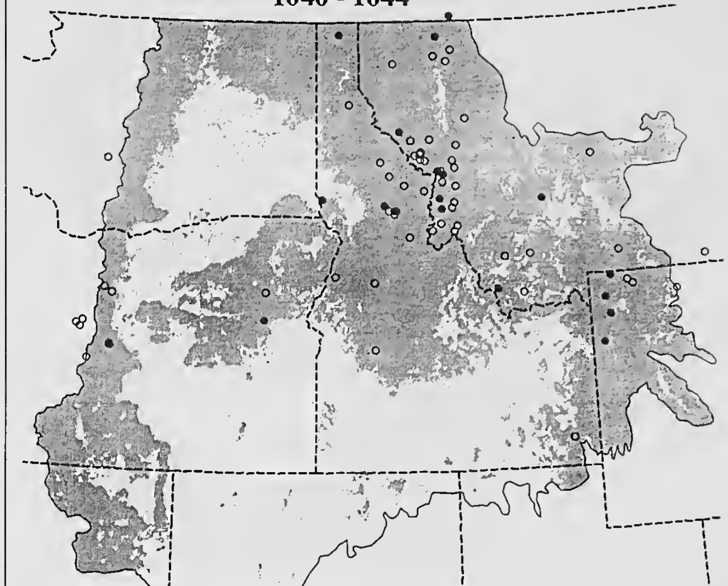


Figure 12

1650 - 1654

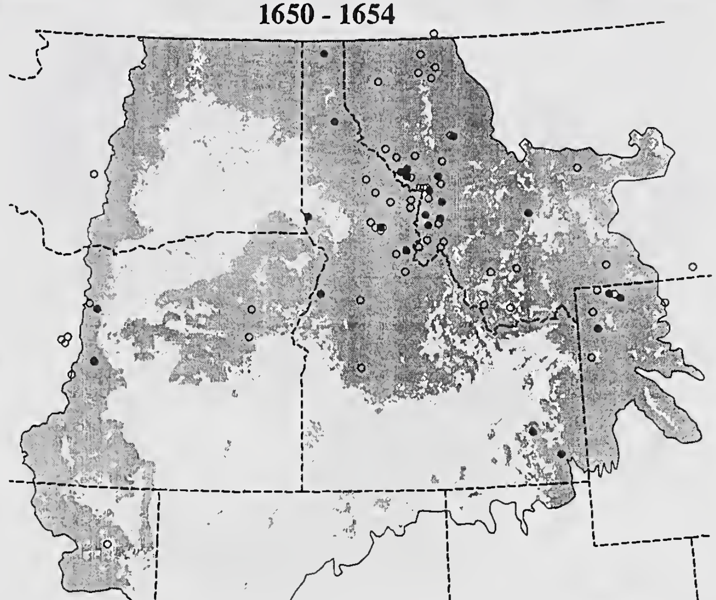


Figure 13

1658 - 1662

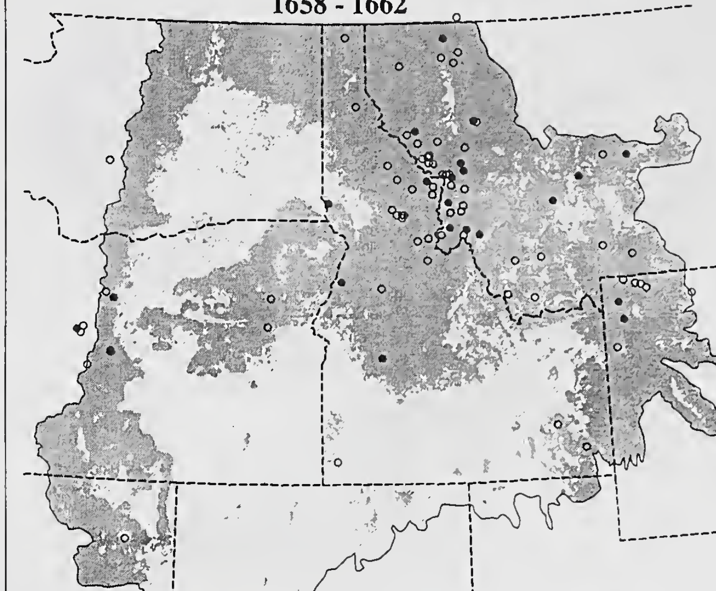
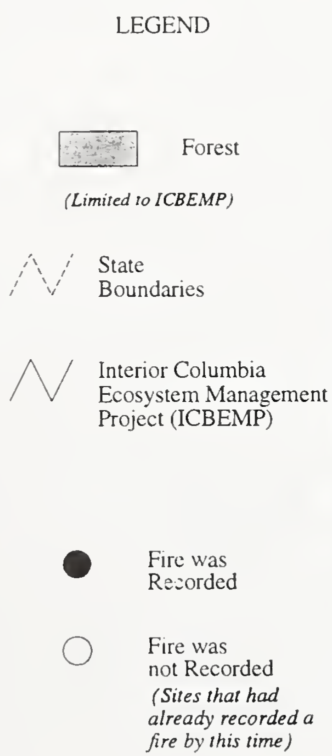


Figure 14



1666 - 1670

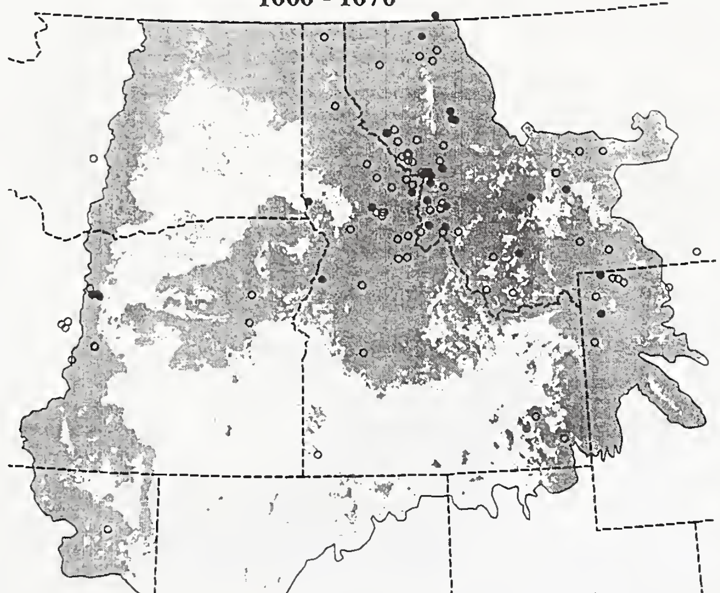


Figure 15

1680 - 1684

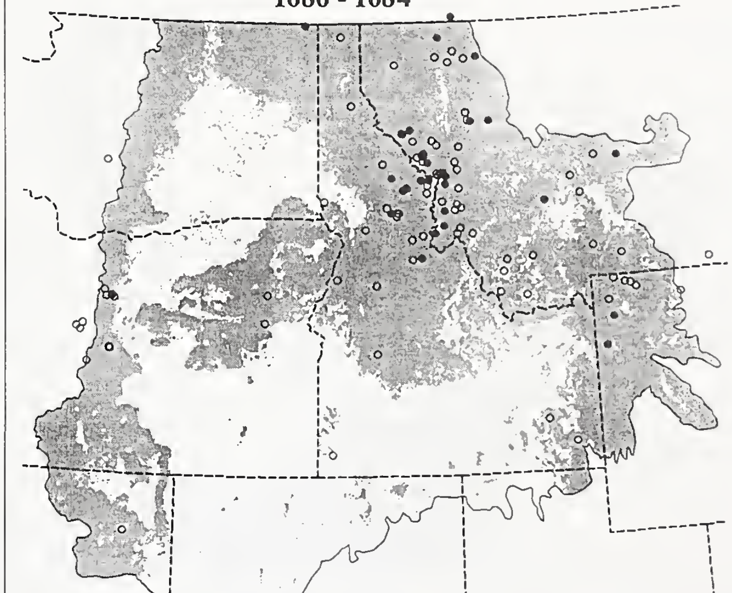


Figure 16

1686 - 1690

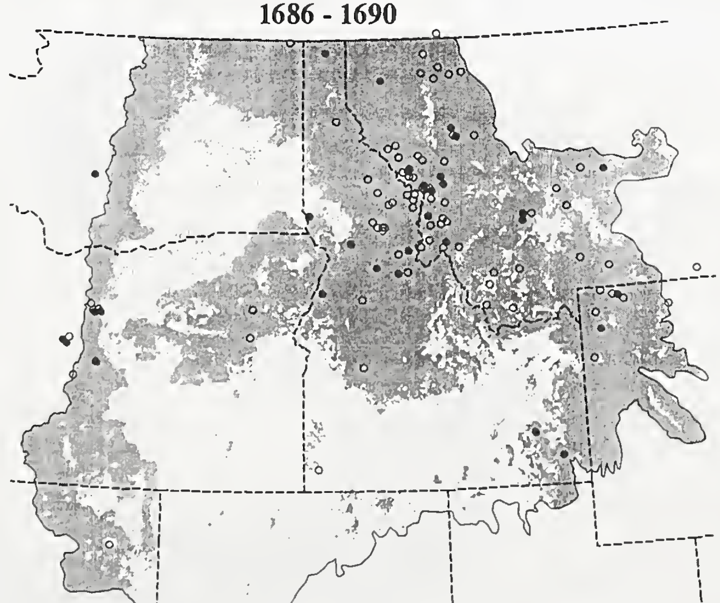


Figure 17

1692 - 1696

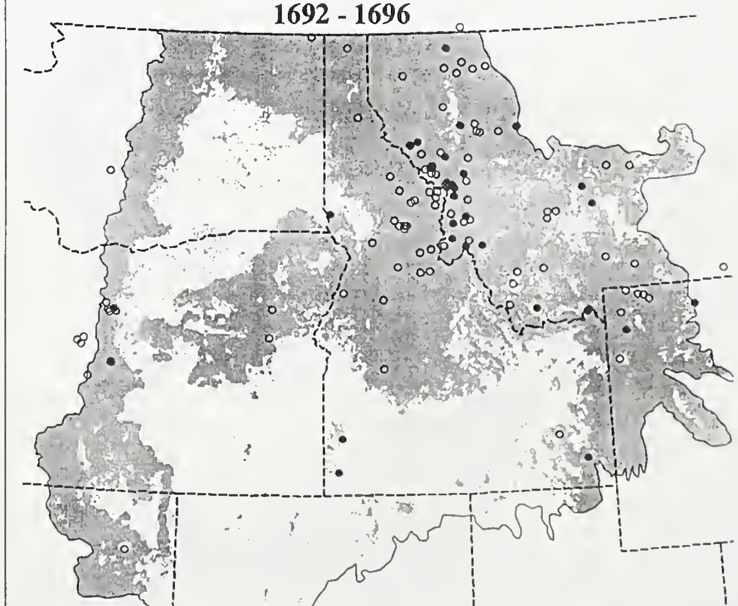


Figure 18

LEGEND

Forest

(Limited to ICBEMP)

State Boundaries

Interior Columbia Ecosystem Management Project (ICBEMP)

Fire was Recorded

Fire was not Recorded *(Sites that had already recorded a fire by this time)*

1701 - 1705

Figure 19

1717 - 1721

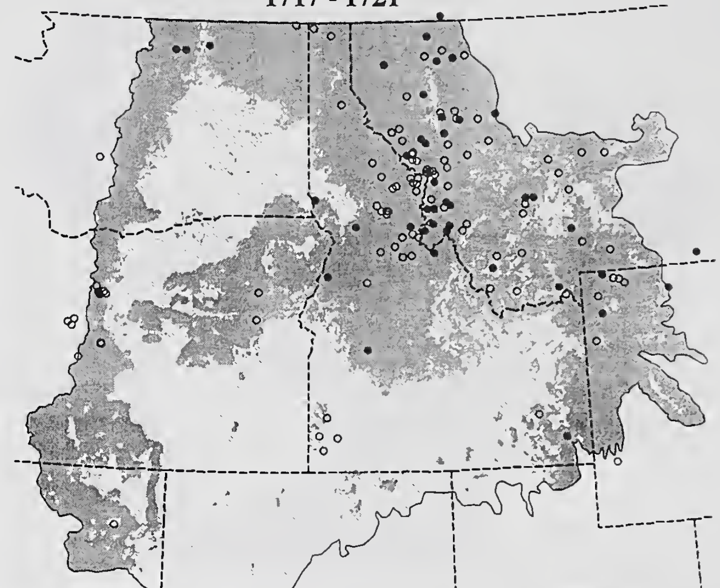


Figure 20

1723 - 1727

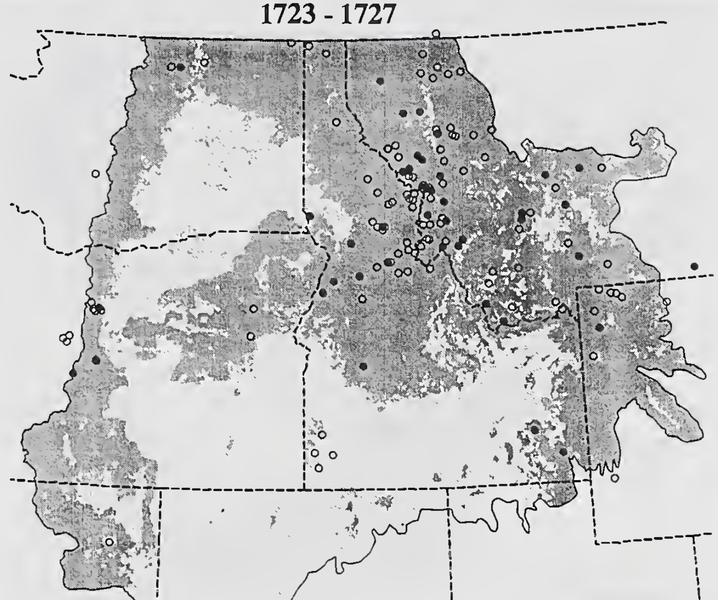


Figure 21

1736 - 1740

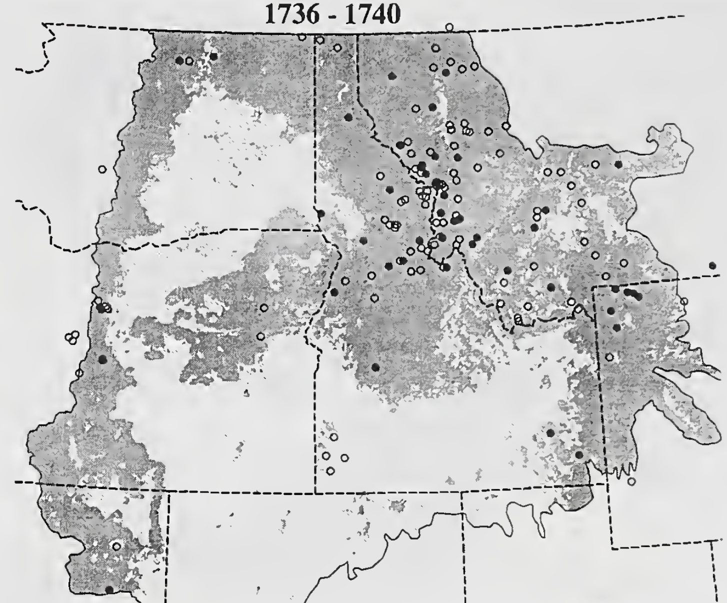


Figure 22

LEGEND

Forest

(Limited to ICBEMP)

State Boundaries

Interior Columbia Ecosystem Management Project (ICBEMP)

Fire was Recorded

Fire was not Recorded *(Sites that had already recorded a fire by this time)*

1748 - 1752

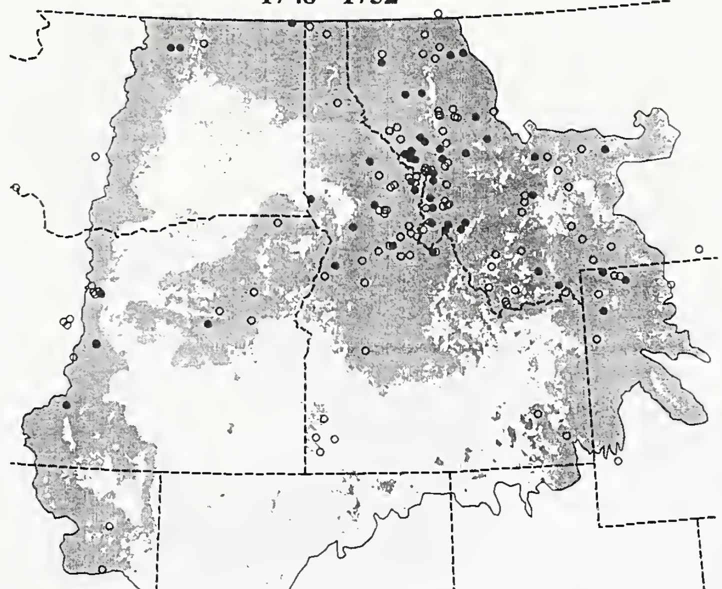


Figure 23

1754 - 1758

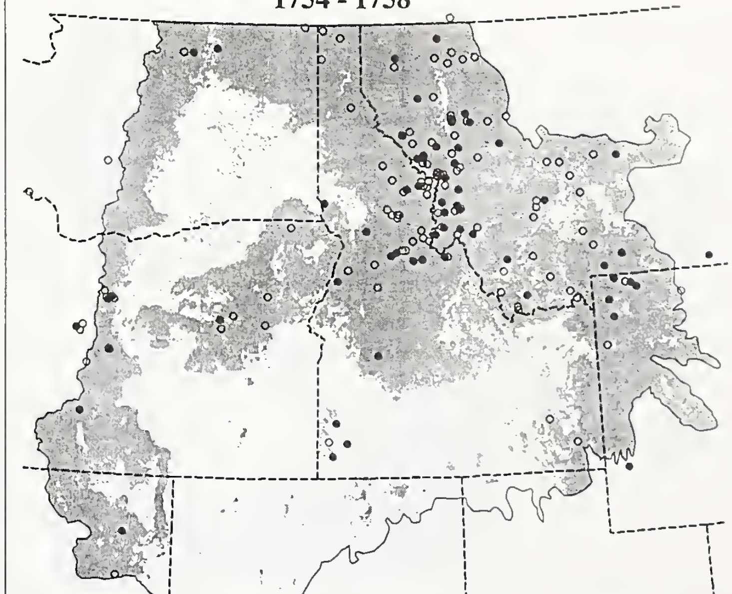


Figure 24

1776 - 1780

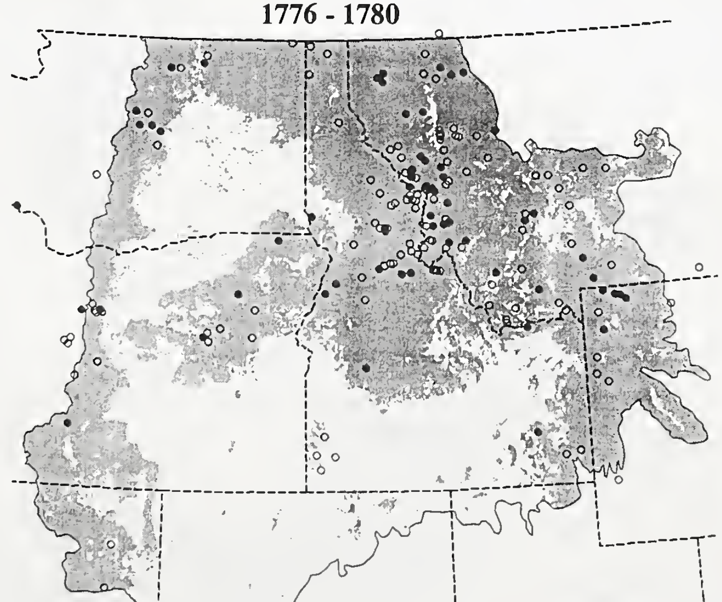


Figure 25

1782 - 1786

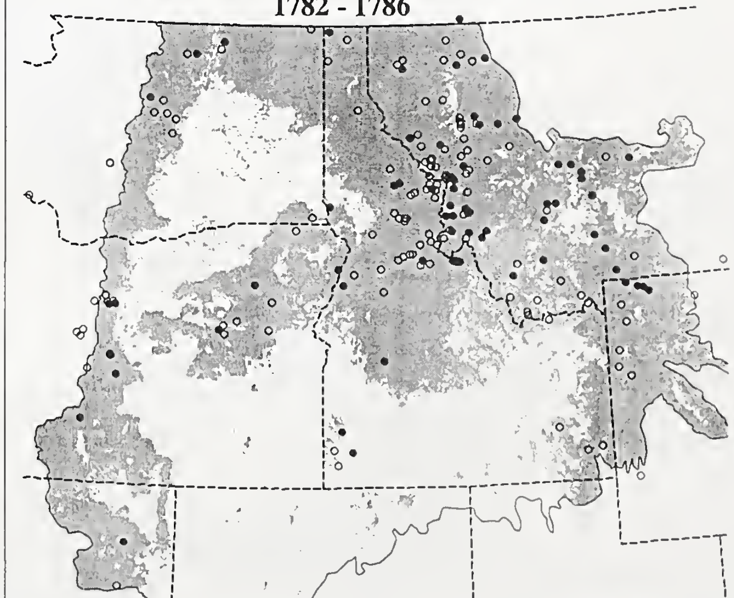


Figure 26

LEGEND

Forest

(Limited to ICBEMP)

State Boundaries

Interior Columbia Ecosystem Management Project (ICBEMP)

Fire was Recorded

Fire was not Recorded *(Sites that had already recorded a fire by this time)*

1800 - 1804

Figure 27

1821 - 1825

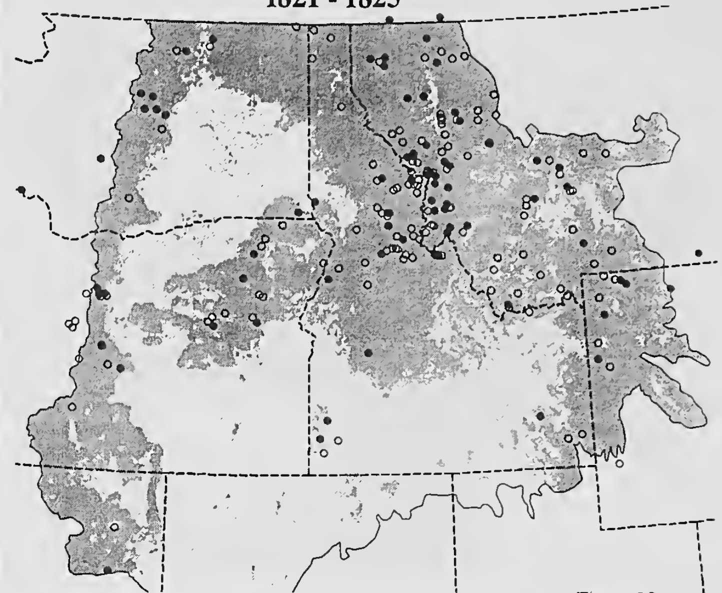


Figure 28

1831 - 1835

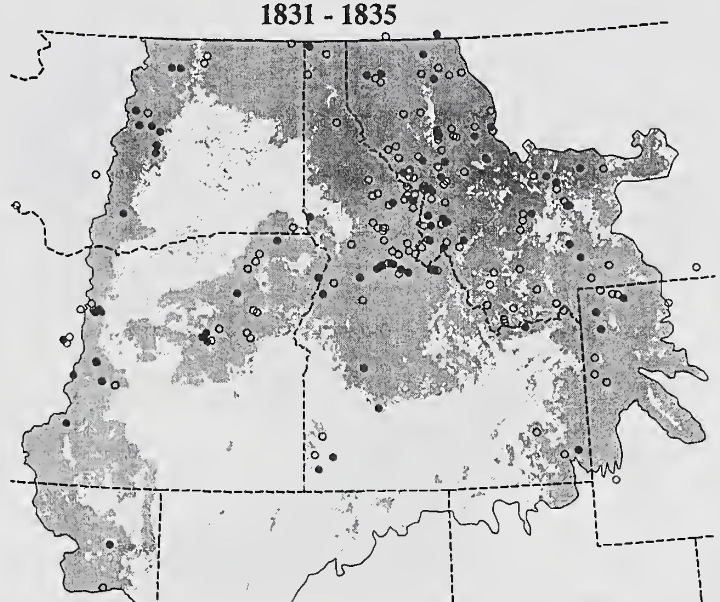


Figure 29

1844 - 1848

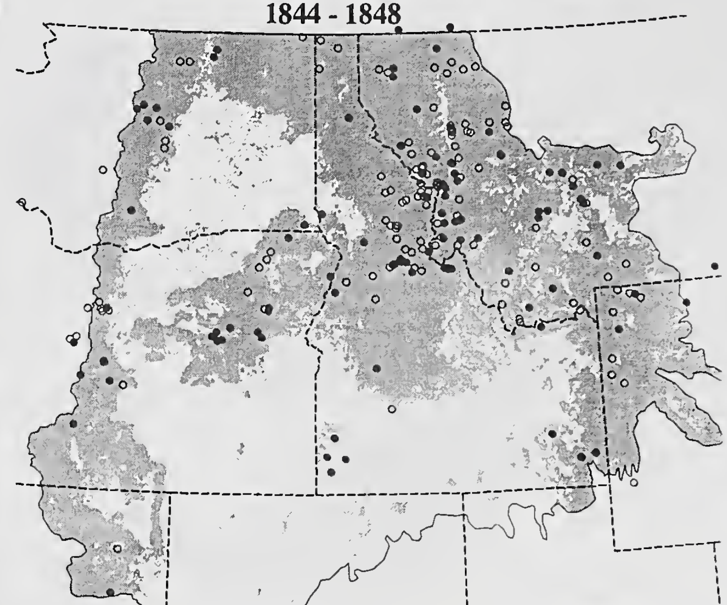


Figure 30

LEGEND

Forest

(Limited to ICBEMP)

State Boundaries

Interior Columbia Ecosystem Management Project (ICBEMP)

Fire was Recorded

Fire was not Recorded
(Sites that had already recorded a fire by this time)

1854 - 1858

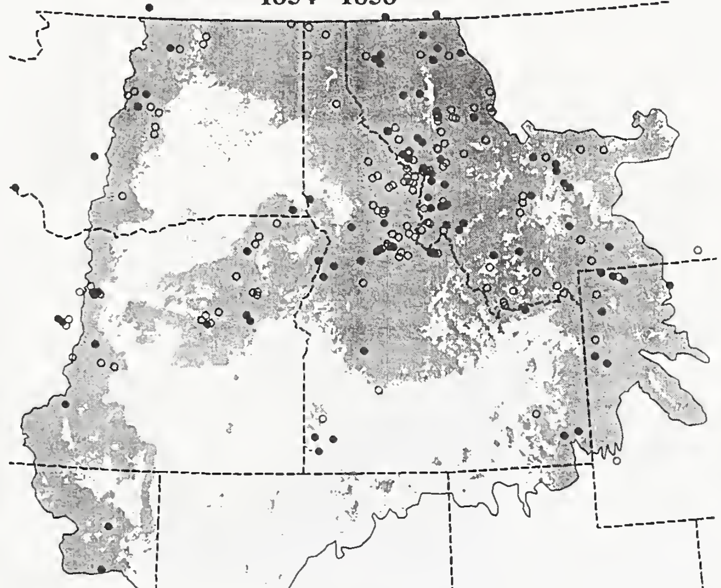


Figure 31

1867 - 1871

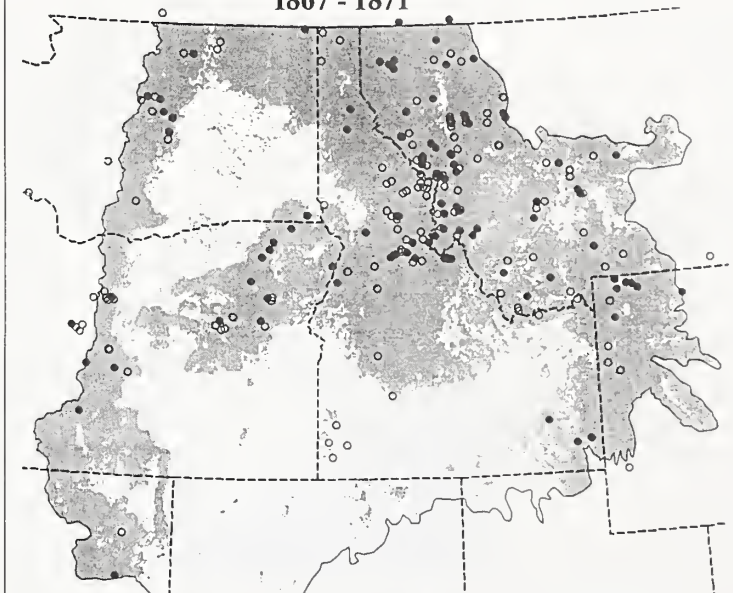


Figure 32

1887 - 1891

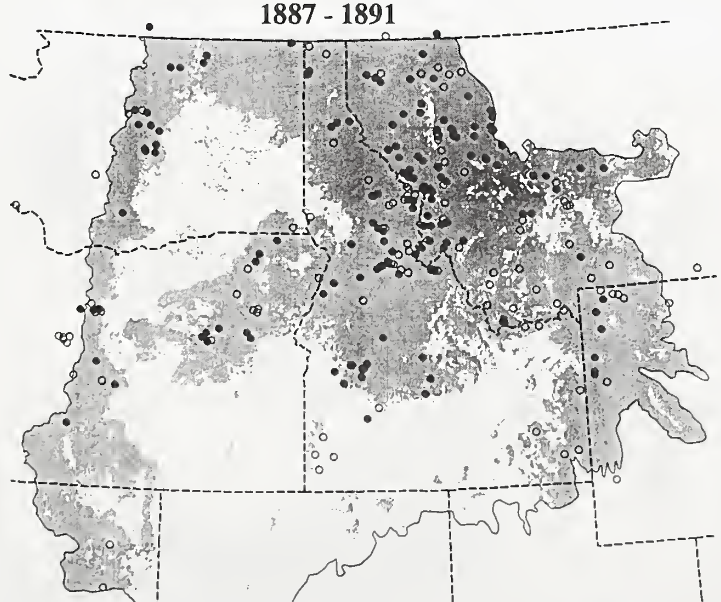


Figure 33

1908 - 1912

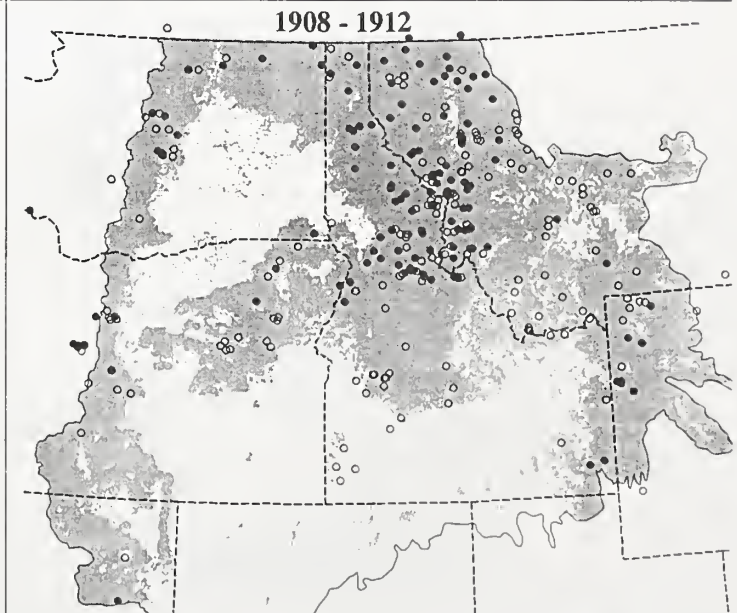


Figure 34

LEGEND

Forest

(Limited to ICBEMP)

State Boundaries

Interior Columbia Ecosystem Management Project (ICBEMP)

Fire was Recorded

Fire was not Recorded *(Sites that had already recorded a fire by this time)*

1917 - 1921

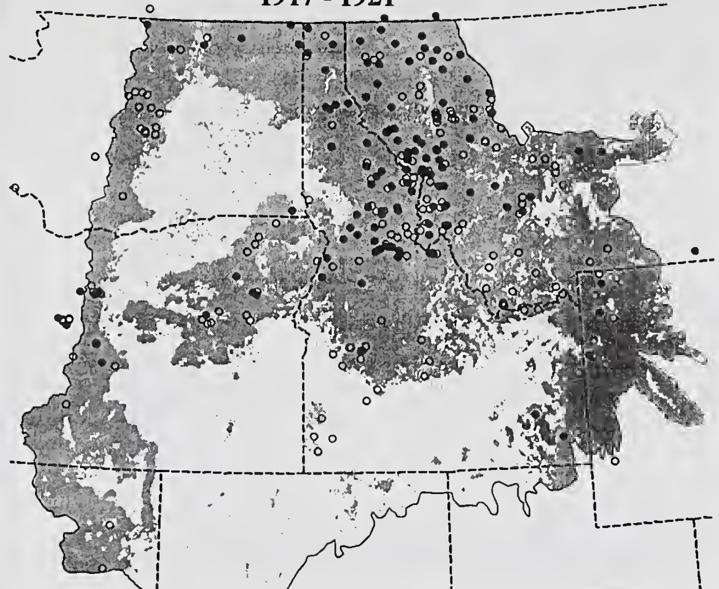


Figure 35

1927 - 1931

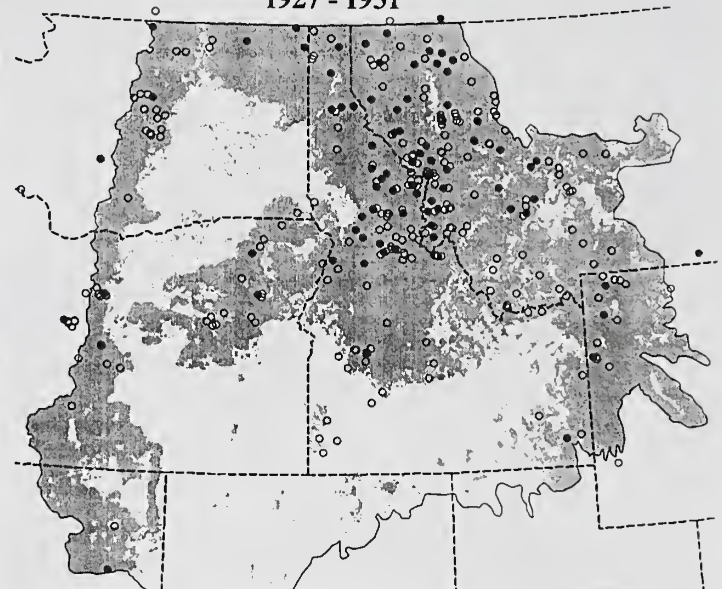


Figure 36

1936 - 1940

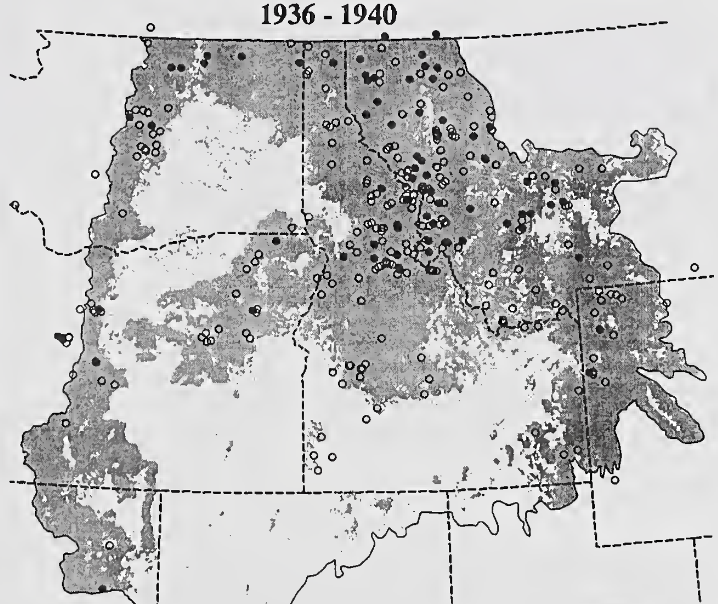


Figure 37

Table 1—Number of study sites recording the 35 fire episodes (when fire data were most abundant), and calculations showing the percentage of sites recording fire per year (fig. 38).

Fire episode	Midpoint year	A Total number of study sites recording the fire episode	B Average number of study sites recording fire per year (A/5)	C Average number of potential recording sites	D Percent of sites recording fire per year
(5 year periods)					*[(B/C) x 100]*
1541-1545	1543	7	1.4	27.2	5.1
1551-1555	1553	7	1.4	30.6	4.6
1563-1567	1565	8	1.6	35.6	4.5
1573-1577	1575	8	1.6	39.8	4.0
1579-1583	1581	12	2.4	42.4	5.7
1592-1596	1594	11	2.2	50.4	4.4
1600-1604	1602	15	3.0	55.0	5.5
1628-1632	1630	17	3.4	68.4	5.0
1632-1636	1634	17	3.4	71.4	4.8
1640-1644	1642	21	4.2	77.6	5.4
1650-1654	1652	26	5.2	85.0	6.1
1658-1662	1660	28	5.6	90.6	6.2
1666-1670	1668	30	6.0	100.4	6.0
1680-1684	1682	29	5.8	109.2	5.3
1686-1690	1688	30	6.0	114.0	5.3
1692-1696	1694	32	6.4	119.6	5.4
1701-1705	1703	38	7.6	127.2	6.0
1717-1721	1719	44	4.8	142.8	6.2
1723-1727	1725	44	8.8	149.2	5.9
1736-1740	1738	52	10.4	157.8	6.6
1748-1752	1750	55	11.0	166.8	6.6
1754-1758	1756	66	13.2	170.8	7.7
1776-1780	1778	69	13.8	191.6	7.2
1782-1786	1784	75	15.0	196.6	7.6
1800-1804	1802	97	19.4	209.8	9.2
1821-1825	1823	86	17.2	216.2	8.0
1831-1835	1833	89	17.8	223.8	8.0
1844-1848	1846	103	20.6	227.8	9.0
1854-1858	1856	98	19.6	230.6	8.5
1867-1871	1869	114	22.8	234.2	9.7
1887-1891	1889	167	33.4	262.6	12.7
1908-1912	1910	149	29.8	301.4	9.9
1917-1921	1919	206	41.2	317.2	13.0
1927-1931	1929	131	26.2	319.2	8.2
1936-1940	1938	98	19.6	323.6	6.1

these intervals, average annual acreages burned in these dry types alone would have been, respectively, 1.2 and 4 million acres.

Principal fire types and average fire intervals of the ICBEMP region are shown in table 2. These vegetation types covered about 80 percent of the ICBEMP region (Losensky 1995) and collectively they had a fire cycle (length of time necessary for an area equal to the entire area of the vegetation types to burn [Romme 1980]) of about 28 years. Other historic forest types that burned at long intervals would have added marginally to the total annual fire activity. Thus, the combined mean annual acreage burned for ponderosa pine, sagebrush-grass, and other forest types in the 200 million acre ICBEMP study region is estimated to have been about 6 million acres.

Substantial year to year variation in the area burned is characteristic of the ICBEMP region (Agee 1993). Annual areas burned from 1916 to 1996 (Arno 1996), indicate that the most active fire years burned double the annual mean acreage, which suggests that major fire years in the historic period would have burned 12 million acres—an area equal to 6 percent of the ICBEMP region. For comparison, the largest known

fire years since 1900 (1910, 1919, 1988, and 1994) have each burned 2 to 3 million acres in the ICBEMP region; about 1 million acres burned in 1996 (Arno, S., records on file at Intermountain Fire Sciences Lab, Missoula, MT).

By the late 1800s, as a result of European-American settlement and associated cultivation, irrigation, and extensive livestock grazing, there were major barriers to the continuity of grassy fuels in much of the ICBEMP region. This restricted the spread of fire (Arno and Gruell 1986), and by the early 1900s, organized suppression was able to greatly reduce the area burned in low intensity fires (Agee 1993). By the late 1940s, total annual acreage burned throughout the western United States had declined (Agee 1993; Arno 1996).

Drought Relationships

Tree ring records from semiarid environments, such as the ponderosa pine type, provide a useful indicator of drought periods during the past few centuries in western North America (Karl and Koscielny 1982; Meko and others 1993). The ICBEMP region's moisture is primarily influenced by a Pacific maritime climatic regime and jet streams tracking inland in a northeasterly direction. During years when maritime moisture systems were scarce, a regional drought pattern developed, which is often reflected in tree ring dendrochronologies (Fritts 1976). Peak fire activity between the 1860s and the early 1920s appears to coincide with regional drought periods (fig. 38). Prior to that time, high fire occurrence and drought periods appear to be less correlated, perhaps as a result of the diminishing data base. A variety of quantitative comparisons were made between drought episodes and relative fire frequencies (Barrett 1995b), but few region-wide linkages between these drought and fire data were evident. Other highly variable factors, such as intraregional weather variations, mass ignitions from large, dry-lightning storms, and occurrence of strong winds during fire events probably accounted for the apparent indirect relationship between drought years and fire. Although long-term drought clearly facilitates burning, the majority of the 166 million acres of vegetation types shown in table 2 experiences short-term drought every year, becoming dry enough to burn for at least a few weeks even in relatively moist years. For example, 1996 was a climatically moist year that experienced short-term drought and a large amount of wildfire activity.

Conclusions and Implications

Fire history data from the ICBEMP region suggest that extensive fire activity occurred at least every decade or two between the mid-1500s and the early 1900s. Calculations of annual acreages burned based on fire intervals for historic vegetation types support past interpretations (Arno 1980; Losensky 1989; Mehringer and others 1977; Pyne 1982) that major fire years prior to the early 1900s burned more acreages than any fire years since then. These calculations support the conclusion of Agee (1993) that changing land use patterns and attempts to exclude fire have succeeded in greatly reducing the scope of fire on the landscape. Conversely, since the late 1970s, there has been a marked increase in annual acreage burned by wildfires in the western United States, including large areas of high-intensity burning in ponderosa pine forests where pre-1900 fires were mostly of low intensity (American Forests 1995; Arno 1996).

On Federal wildlands such as National Forests, fire is now recognized as an important ecological process (USDI and USDA 1995). Unwanted wildfires will continue to be a major agent of change on landscapes of the ICBEMP region. However, today there is growing interest in a proactive approach to guide the fire process. This involves using prescribed fire and fuels management silviculture in appropriate ways to help restore and maintain biological diversity as well as sustainable commodity and aesthetic values on Federal wildlands (Babbitt 1995; Hardy and Arno 1996; Williams 1995).

Table 2—Estimated areas of historic vegetation types in the ICBEMP study region (fig. 1) and average annual rate of burning.

Cover type	Estimated acreage[a]	Mean fire interval[b]	Mean annual acreage burned
	Millions of acres	*Years*	*Millions of acres*
Ponderosa pine	24.0	20	1.20
Sagebrush and bunchgrass	100.0	25	4.00
Interior Douglas-fir and larch	19.0	52	0.36
Western juniper (*Juniperus occidentalis*)	6.5	52	0.13
Lodgepole pine	17.0	112	0.15
Totals	166.5		5.85

[a]from Losensky (1995).

[b]Ponderosa pine, Interior Douglas-fir, and lodgepole pine fire intervals are from Barrett (1995) database. Sagebrush-grass is an estimate based on Wright and Bailey (1982). Western juniper was based on the same interval as Douglas-fir (Arno 1985).

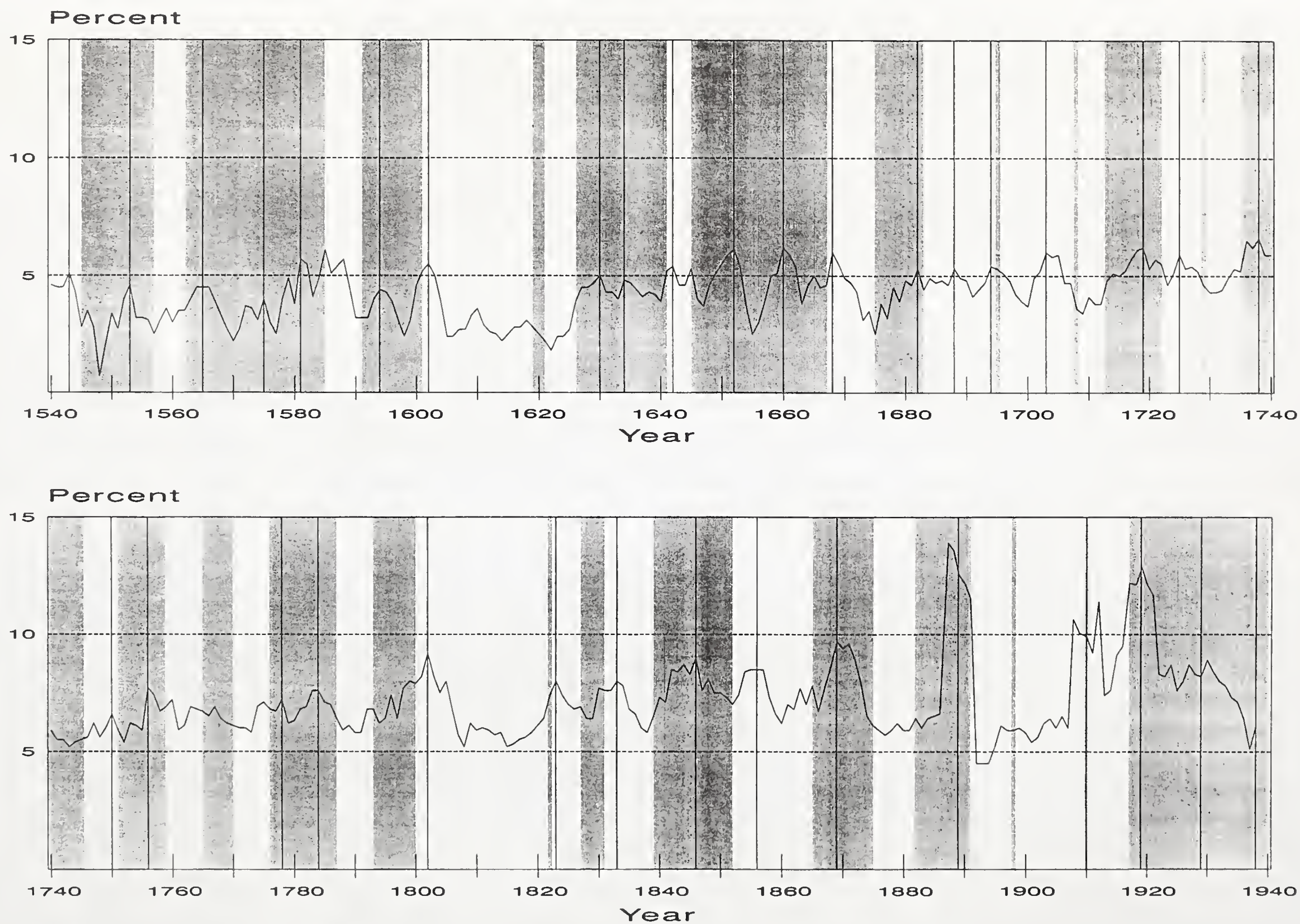


Figure 38—Fire occurrence across the ICBEMP region based on the study sites that recorded a fire divided by the total number of study sites that had begun recording fires by that year (table 1). Percentages were based on a 5 year running average that surrounded a specific year (plus and minus 2 years). The upward trend in percentage with more recent years probably results from more complete records of fires. The black vertical lines indicate the mid-points of the 35 fire episodes. Areas shaded in gray delineate periods of regional drought.

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Presents maps of major fire episodes in the inland northwestern United States between 1540 and 1940 based on a compilation of fire history studies. Estimates annual acreage historically burned in this region and compares that with recent fire years.

Keywords: landscape ecology, disturbance patterns, wildfire, prescribed fire, Columbia River Basin

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